ARTICLE XXVIII.

On the Relative Horizontal Intensities of Terrestrial Magnetism at several Places in the United States, with the Investigation of Corrections for Temperature, and Comparisons of the Methods of Oscillation in Full and in Rarefied Air. By A. D. Bache, Professor of Natural Philosophy and Chemistry, and Edward H. Courtenay, Professor of Mathematics, in the University of Pennsylvania. Read May 6th, 1836.

The observations for horizontal intensity which we are about to present to the Society were commenced in the spring of 1834, and have been continued at intervals since that time. The first series was made with the usual apparatus, namely, a needle, suspended by a fibre without torsion, and made to vibrate in a closed box. The second series was obtained by oscillating the needles in rarefied air. These latter observations having proved satisfactory, we should be able to determine the total intensities at the several places of observation, were the dip determined with a sufficient degree of minuteness. While our observations with the ordinary dipping-needle already published by the Society,* show approximately the variations of that element, a minute variation in the angle affects, when the dip is so large, so considerably the total intensity, that we do not feel warranted at present in combining those results with the horizontal forces.

* American Philosophical Society's Transactions, Vol. V., (Part II.) page 309.

In the present state of the experimental part of this branch of science, we are induced to present these observations, not only as showing the horizontal intensities at the different places of observation, but on account of the deductions warranted by the investigation of corrections for temperature, and the comparison afforded between the methods of oscillation in full air, and in a rarefied medium. This latter mode is so great an improvement, that its claims cannot be too strongly urged.

The most numerous observations of the first series above referred to, were made at Philadelphia and West Point. These presented discrepancies which we were entirely at a loss to explain.

The differences, in the time of ten vibrations, as observed on different occasions at the same place, were of an amount entirely beyond what could have resulted from errors of observation, which the method of observing rendered quite small. Pains had been taken, in all cases, to remove magnetic matter which might have affected the results; and in other respects the observations were carefully made.

Some part of the discrepancies might be charged to the errors in the time-pieces used. The observations at West Point were made however, with a chronometer of undoubted reputation, and most of those at Philadelphia, with chronometers of good standing; and the discrepancies could not thus be satisfactorily accounted for.

The magnetic needles used had not changed their magnetism during the series of observations, and were thus shown to be sufficiently hard to retain their charge. It was not probable, therefore, that they would readily change, from day to day, their magnetic state, unless from changes in the earth's magnetism, or from heat. A correction for temperature was ascertained by experiment, and the results show that this correction was accurate. Without it the amount of the differences is very much increased.

It is possible, that in some of the earlier observations in the first series, sufficient care was not taken to allow the needles to attain the temperature of the surrounding medium, a source of error which was guarded against in the later results.

The discrepancies seemed to us to show, either that there was some imperfection in the apparatus, other than those already enumerated, or

that the magnetism of the earth really undergoes frequent and considerable changes. This latter point seems to be generally conceded, but we do not think upon sufficient grounds.

Mr Harris,* of Plymouth, had already pointed out the effect of currents of air within the apparatus in which the needle is inclosed, as rendering this method of experiment objectionable. He had proposed to remove this objection by oscillating the needles in a rarefied medium, and had devised an apparatus for this purpose. Mr R. W. Fox had noticed the same defect.† It first occurred to us in full force when observing for the correction for temperature. This source of error was particularly active in the case of the needle of the smallest mass, oscillating rapidly, and, as is usual, in large arcs, at the commencement of the motion. To get rid of this cause of error, we resorted to the method proposed by Mr Harris, and had constructed a stationary, and also a portable apparatus for vibrating in a rarefied medium. The stationary apparatus was intended to investigate the supposed changes of the horizontal intensity from day to day, and the portable apparatus to repeat the observations made in the first series at several different places.

Our expectations of the superior accuracy of observations in a rarefied medium, were not disappointed. We had laid aside our first series of results as unsatisfactory, and now propose to use them only when the observations were very numerous. A comparison of their mean error with that of the series in the rarefied medium, will serve to show, that they have little weight when the number is not very much multiplied, in comparison with the latter.

It was stated that arrangements had been made by Mr Harris for determining the relative intensities at certain places in England, by a needle oscillating in rarefied air; but we believe that our results are the first of this kind which have been offered to the public. The method of vibrations in air continues to be used, and, if our views of its imperfections are correct, the importance of our results is consi-

* W. Snow Harris, in the Trans. of the Royal Society of London, 1831, pp. 67, 68, &c.

† R. W. Fox, in the London and Ed. Philos. Mag., Vol. I., p. 310, &c.

derably beyond what could be claimed for the mere determination of the horizontal intensities at the several places of observation.

These and other circumstances render it imperative upon us to give the observations in detail, and will, we trust, excuse to the Society the length of our memoir.

OF THE INSTRUMENTS.

The needles used in the FIRST SERIES for horizontal intensities were of the form originally adopted by professor Hansteen, namely, cylinders terminated by cones. They were three in number, and of different masses. These were in turn suspended by one or more fibres of silkworm's thread in a small box which protected them from the air, and at the bottom of which was placed a graduated circle. Two threads were fastened vertically against two small glass windows in the sides of the Box, and in a plane passing through the centre of the divided circle. These threads, when brought into the plane of the magnetic meridian, served to observe the passage of the ends of the needle across this plane. Three levelling screws were attached to the bottom of the box. The method of adjusting for the level of the needle, and of the box, for placing the line of suspension in the direction of the threads, and bringing them into the meridian, and for centring the needle, are too simple to need any particular description. The needles were placed in small stirrups, and were raised, usually, about half an inch above the bottom of the box.

Needle No. 1, the largest, was three inches long, and .22 in diameter in the cylindrical part. It was placed in a brass stirrup, and suspended by two fibres of silkworm's thread. This needle was most steady in its vibrations, and did not lose any appreciable part of its magnetism while in use, though it was softer than No. 3.

No. 2 was of the same material as No. 1. Its length was 2.53 inches, and diameter of the cylinder .22 inches; weighing, with its stirrup, 203 grains. Both of these needles were made at West Point, and they were not highly charged.

The observations made with the latter needle, No. 2, were few in number, and they were neither considered at the time of the observa-

tions, nor proved by their agreement with those made with Nos. 1 and 3, to be satisfactory, we have thought it best not to use them in taking our mean. We have placed the description of the needle here, because the correction for temperature was observed, and we are enabled to use the results in their bearing upon the general conclusions in regard to the effect of heat on the intensity of the magnet itself.

No. 3 was of the Hansteen model, 2.43 in length, and .14 inch in diameter, at the cylindric part; weighing, with its pasteboard stirrup, 78 grains. For this needle, we are indebted to our friend, professor Henry, of Princeton, by whom it was made and magnetized, several years since. Its rate is slower than that of either Nos. 1 or 2.

The needles were kept in separate boxes, and when stationary, or carried from place to place, the cases containing them were kept as far as possible from each other, and from iron or steel.

Observations were made at Philadelphia and West Point, with a fourth needle, C of *second series*, but the results were very little accordant. This we attribute to its small mass, and the rapidity of its vibration. So materially was this needle affected by accidental circumstances, that its small correction for temperature not only was masked by them, but was even, apparently, negative under their influence. In a rarefied medium the performance of this needle was very regular and satisfactory.

In the Second Series of observations, upon which we principally rely, three needles were used. The first, A, was a small bar 2.83 inches long, and .22 by .14 of an inch in cross section, the larger dimension being vertical. The weight of the bar, and of its suspending stirrup of wire, was 184 grains. It was suspended by three silk worm threads, and made, when in a medium rarefied to between three and a half and three inches of mercury, three hundred vibrations, between the semi-arcs of four and two degrees. A small black line on a white ground, upon one end of the needle, served to observe its passage over the meridian, when oscillating.

The second needle, B, was No. 3 of the first series. It was placed in a pasteboard stirrup, which made its moment of inertia slightly different from that in the first series. It made about two hundred and fifty

vibrations between the semi-arcs of six and two degrees, in a medium rarefied to between three and a half and three inches of mercury.

The third needle, C, was the fourth of the first series. It made, between the semi-arcs of six and two degrees, three hundred vibrations, at the pressure just referred to. The length of this needle was 2.36 inches. The diameter of the cylindrical part .14 of an inch, and the weight of the needle and paper stirrup in which it was hung 72 grains.

The apparatus in which these needles were oscillated, consisted of a small jar, furnished with a brass cap, screwing into a ring cemented around the mouth of the jar. Attached to this cap was a siphon gauge to show the pressure within; a lateral tube, or passage, from the jar, terminated by a screw, served to apply a small syringe for the purpose of exhausting the jar. The tube was closed by a valve of oiled silk, which acted as one of the valves of the air-pump. A metallic stem, passing through a collar of leathers, occupied the centre of the plate; and the needles, being suspended by a hook at the end of this stem, were raised or lowered by means of it, as occasion required. A scale for measuring the arcs of vibration was fastened around the exterior of the jar. The smallness of these arcs rendered minute accuracy in their measurement of no importance.

A jar of the requisite form not being at hand, one of ordinary height in proportion to its diameter, was partly filled with cement, so as to diminish the space within. The height of the part of the jar in which the needle vibrated, was about three and a half inches, and its diameter nearly the same. The needles swung about .6 of an inch from the cement floor. This jar was particularly adapted to needle A.

A thermometer placed within the jar completed this apparatus. The parts being readily detached, the whole was very portable.

METHODS OF OBSERVATION.

In the commencement we adopted the method used by Captain Sabine, and described in the Royal Society's Transactions, London, for 1828. We have subsequently adopted another method, which not only saves much labour, but is, we think, quite as unexceptionable in

a theoretical point of view, as the one just referred to. This is, simply, to note the time of beginning and ending of a considerable number of vibrations, with the arcs of vibration at the commencement and end.

In practice, the needle having been made to oscillate, and having arrived at the arc previously fixed upon for beginning the observations, the time of passing the meridian is noted. The oscillations continuing, when the arcs have decreased to the point intended for terminating the experiment, the time of passage is again observed. The interval is the time of making the observed number of oscillations. If it were necessary to count this number without any checks upon the counting, the method would be tedious and liable to mistakes, but this is not the case. If the time of a given number, for example, of ten oscillations has been found approximately, and the time of passage of the needle over the meridian be always observed when the same end is moving in the same direction, there can be no doubt of the number of vibrations corresponding to an observed interval, until the difference between the quotient of the observed interval by a number greater or less by two than the true number of oscillations, is less, than the limit of accuracy with which the time of the supposed number of oscillations is known.

To furnish convenient numbers for calculating the time of ten oscillations, we observed usually at the end of fifty or one hundred oscillations, a number much below the limit allowed by the condition just referred to. An example will serve to show how fully this method, when properly applied, is to be relied upon.

Philadelphia, September 19th, 1835. Needle A.

Observed times of passage over the magnetic meridian.

	h.	m.	s.
P. M.	5	35	17.8
		31	18.0
		37	18.0
		43	18.0

The time of ten vibrations being known to be between 36 seconds and 36.4 seconds, there can be no doubt as to the number of vibrations corresponding to either of the intervals deduced from the observa-

tions just given. One hundred oscillations gives, from the interval between the first and second observations, 36.2 seconds, for the time of ten vibrations, while ninety-eight gives 36.75 seconds, and one hundred and two, gives 35.31 seconds for the same time. There is more certainty than could have been obtained by counting the whole number of vibrations, and quite as much as if each ten had been counted, and the time corresponding to it noted, as in the method usually practised.

The time of ten vibrations can obviously be found within the required limit of accuracy by one or two sets of ten vibrations, counted at the beginning of the experiment. When the limit of accuracy is fixed, it is easy to determine how many pairs of vibrations the needle may make before another observation for the time of passage is necessary.*

CORRECTIONS FOR TEMPERATURE.

In determining these corrections, we proceeded upon the principle usually assumed, that to equal increments of temperature correspond equal diminutions in the magnetic force of the suspended needle. This is, no doubt, approximately true within a moderate range of temperature. We also assumed, that the magnetic state of the needle is the same at the same temperature. The formula of professor Hansteen, based upon these suppositions, is,

$$T = T'\left(1 - m\,(t' - t)\right),$$

where T represents the time of making a certain number of oscilla-

* The following simple investigation will serve to determine the greatest admissible number of vibrations between two consecutive observations.

Let t = the time of 10 vibrations; n = the true number of vibrations in the whole time; e the greatest error in the observed time of 10 vibrations.

Then, $\frac{n\,e}{10}$ = the greatest error in estimating the whole time. That there may be no doubt as to the true value of n, we must have $\frac{n\,e}{10} < \frac{t}{10}$, or $n < \frac{t}{e}$.

To exemplify this, in regard to needle A, suppose $t = 36$ seconds, $e = .2$ second, we must have $n < \frac{36}{.2} < 180$.

lations at the temperature t, T$'$ the time of making the same number at the temperature t', and m is a constant to be determined by experiment, from the equation

$$m = \frac{T' - T}{T'(t' - t)}$$

The effect of the expansion of the needle upon its moment of inertia is, of course, too minute to enter into the discussion. The method adopted for finding this coefficient was similar to that described by Captain Sabine.* The observations in the first series were made in the small magnetic observatory, where most of the observations at Philadelphia were made.

In the First Series the arrangements for observing were as follows. The apparatus for oscillating was placed in a large wooden vessel, forming a considerable inclosure around it. The temperature of the inclosure, and of course of the apparatus, was lowered by filling around the latter with ice, the melting of which was occasionally promoted by sprinkling with salt. The top of the inclosure was covered, except only a sufficient space to look down upon the northern half of the needle, and upon the thermometer within the box. Access of air, and radiation from the sides of the observatory, were thus, in a great measure, cut off. A local dew point resulted from this arrangement, within the inclosure, which prevented embarrassment from the deposition of moisture upon the needle, or upon the glass cover of the box.

The needle to be observed having been allowed to remain in the box a sufficient length of time to acquire the temperature of the medium within, the experiment was commenced. The temperature of the box was noted, by the inclosed thermometer, at intervals during the oscillations, the temperature being made as nearly stationary as possible. The mean temperature thus obtained does not, of course, coincide with the half sum of the temperatures taken at the beginning and end, and which are recorded with the means in the table which follows.

The observation of the passage of the needle over the meridian, and of the arcs of vibration, had been rendered easy and accurate by tracing

* Brande's Quarterly Journal of Science, Vol. XXVIII. p. 14, &c.

on the glass cover of the box a zero line and graduations, similar to those on the scale at the bottom of the box.

Some of the results were carried from semi-arcs of twenty-five to three degrees, but the observations below the semi-arcs of five degrees are omitted. The series thus requires no correction for arc, to obtain relative results. The observations made below five degrees were not as accordant as those above; they were, however, few in number.

The experiments just detailed occupied almost the entire interval between $10\frac{1}{2}$ A. M. on the 25th, and $12\frac{1}{2}$ A. M. on the 26th of August 1834; they are, therefore, affected by the diurnal variation. Needle No. 1 was vibrated at intervals to determine the amount of this correction; but the nature of the results did not warrant the use of any correction derived from this source.

The following table contains the record of the observations just referred to. The several columns contain, first, the number of the experiment, for reference; second, the designation of the needle; third, fourth and fifth, the times of beginning and ending the oscillations; sixth, the temperatures at the beginning and end; seventh, the number of oscillations between the semi-arcs of twenty and of five degrees; eighth, the mean temperature; ninth, the time of ten vibrations.

TABLE No. I.

Observations for Correction for Temperature of Needles 1, 2 *and* 3.

No. of Experiment.	No. of Needle.	Times of Beginning and End.			Temperatures at Beginning and End.	No. of Vibrations.	Mean Temperature.	Time of Ten Vibrations.	Observers' Names, &c.
		Hours.	Mins.	Secs.	Fah.°		Fah.°	Secs.	
1.	1.	P.M. 12	38	44.0	36				August 25th, 1834.
		1	08	08.6	32	390	33.6	45.25	Bache.
2.	"	P.M. 4	30	19.2	$35\frac{1}{2}$				
			56	00.2	$35\frac{1}{2}$	340	35.7	45.32	Bache and Courtenay.
3.	"	P.M. 8	04	00.0	98				
			31	40.5	100	356	99.1	46.64	Bache and Courtenay.
4.	"	P.M. 11	51	16.4	98				
		A.M. 12	19	20.8	98	362	98 0	46.53	Bache. (August 26.)
5.	2.	P.M. 1	44	35.8	32				
		2	09	14.6	$32\frac{1}{4}$	340	32.2	43.50	Bache.
6.	"	P.M. 10	42	47.8	98				
		11	14	25.8	102	424	99.3	44.77	Bache and Courtenay.
7.	3.	P.M. 2	36	45.0	35				
			50	24.6	36	170	35.3	48.21	Bache.
8.	"	P.M. 9	51	22.2	102				
		10	06	16.2	$102\frac{1}{2}$	182	102.2	49.12	Bache and Courtenay.

The time was observed by a good pocket chronometer, making one hundred and fifty beats per minute, and the observed times of beginning and end are given to four-tenths, and probably with accuracy even to two-tenths of a second.

The irregularity in the number of vibrations between two given arcs was observed very generally in the first series of experiments, and is probably, in a great measure, due to the imperfect mode of estimating the arcs. It has little or no effect on the accuracy of the results, since even at the largest arcs many successive vibrations will be performed in times not differing appreciably from each other.

The coefficient for the correction for temperature of needle No. 1, as deduced from the experiments just given, is,

From experiments 1	and	3,	$m =$	.000,455
1	"	4,	$m =$	.000,427
2	"	3,	$m =$	.000,446
2	"	4,	$m =$	.000,417
Mean,			$m =$	.000,436

Although it appears rather obvious that these several corrections do not differ essentially from the mean, it may not be amiss to show that the difference in the time of ten vibrations produced by using either of them, is within the probable limit of accuracy of the separate observations. By applying the first coefficient, which differs more from the mean than either the second or third, to deduce the time of ten vibrations at 98° Fah. from the observed time at 33.6, as given in the preceding table, we have 46.58 seconds: while the mean coefficient, similarly applied, gives 46.52 seconds, differing but .06 of a second in the time of ten vibrations. If now it be considered that these extremes of temperature are much further apart than in the cases occurring in the use of the needles, and further that the observations are to be reduced to a selected mean temperature, the result seems entirely satisfactory.

The coefficient for the reduction for temperature of needle No. 2, deduced from experiments five and six of the foregoing tables, is, $m' = .000,423$. That for No. 3, is $m'' = 000,277$.

No permanent change in the magnetic state of either of the needles was produced by the elevation of temperature to which they were subjected in these experiments.

In the SECOND SERIES of observations, the correction for temperature of Needle A, was obtained immediately after the observations at the different stations had been completed. As in the experiments already given, the temperature of the needle was lowered by ice, and raised by the heat from spirit lamps, placed in the same inclosure with the jar.

It was not convenient to observe the other needles at the same time, and the corrections applied to them were obtained in February, and within doors. Two questions were thus suggested: first, whether the correction for temperature is sensibly the same at different seasons, or whether a variation in the earth's magnetic intensity may produce a change in the distribution of the magnetism of a needle, so as to render it more or less liable to have its state changed by heat. Second, whether the local magnetism proportionably affects the magnetic state of a needle at different temperatures. As far as the practical use of the correction for our observations is concerned, both these questions were resolved. And from the answer, we felt warranted in deducing the corrections for the needles B and C, as above stated.

All the observations were made with the same thermometer which was used to give the temperature of experiment of the different stations. The observations for the correction for needle A, are contained in the following table, of which the form is similar to that before given. A column is introduced for the height of the gauge, and two others to contain the mean of the separate determinations at each temperature.

TABLE No. II.

Observations for the Correction for Temperature of Needle A.

No. of Observation.	Times of Beginning and Ending. Hours.	Mins.	Secs.	Temperature at Beginning and End. Fah.°	Height of Gauge. Inch.	Number of Oscillations.	Mean Temperature. Fah.°	Time of Ten Vibrations. Secs.	Mean Temperature of each set of Observations. Fah.°	Mean Time of Ten Vibrations in each set. Seconds.	Observers.
	P.M. 4	14	26.4	72							October 5th,
	"	32	27.8	"	3	300*	72.0	36.05			1835.
		34	30.8	72							Bache and
1.		52	32.0	$70\frac{1}{2}$	4	300†	71.2	36.04	71.6	36.045	Courtenay.
	P.M. 6	31	57.2	36							
		46	55.2	32	4‡	250	33.7	35.92			
	6	59	07.6	32							Bache and
2.	7	17	04.0	36	$3\frac{1}{2}$	300	33.7	35.88	33.7	35.900	Courtenay.
	P.M. 8	42	23.2	61							
	9	00	23.6	62	$3\frac{3}{4}$	300	61.7	36.01			
	9	02	55.2	62							Bache and
3.		20	56.2	64	4	300	62.9	36.03	62.3	36.020	Courtenay.
	P.M. 10	29	24.4	92							
		44	28.0	90	$4\frac{1}{4}$	250	91.2	36.14			
	11	10	33.2	86							
4.		28	38.2	91	3	300	88.5	36.17	89.8	36.155	Bache.

The second set of observations was introduced to ascertain the allowance to be made for the diurnal variation of intensity. Reducing it to the temperature of the first set by using the mean coefficient from the entire series, it shows an increase in the time of ten oscillations between 4 and 5 P. M., the mean hour of making the first set, and 9 P. M., the mean hour of the third, of .022 seconds. Applying the proportional part of this correction to the sets numbered 2 and 4, the temperatures and times will be found to be as follows,

No. 1, 71.6°, 36.045 seconds.
2, 33.7°, 35.888 "
4, 89.8°, 36.124 "

And the corrections deduced from a comparison of the several sets will be more accordant, than when the daily variation is not considered. The values of the coefficient are,

* Terminated in an arc rather greater than two degrees.
† Terminated in an arc rather less than two degrees.
‡ Above four inches.

From Nos. 4 and 2, $m = .000{,}116$
" " 4 " 1, $m = .000{,}120$
" " 2 " 1, $m = .000{,}115$

Mean $m = .000{,}117$

It appears distinctly, from comparing these results, that the change of intensity of the needle's magnetism is greater at the higher temperatures than at the lower, for equal changes of temperature. The value of m, deduced from observations between 72° and 90°, is the greatest; next the value obtained between 34° and 90°, and last that between 34° and 72°. This change would have appeared greater if no correction had been made for the daily variation.

The second and third sets of observations on needle A, before referred to, are given in the annexed table. The object of these sets has already been explained.

TABLE No. III.

Observations for the Correction for Temperature of Needle A.

No. of Observation.	Times of Beginning and Ending.			Temperature of Beginning and Ending.	Height of Gauge.	No. of Vibrations.	Mean Temperature.	Time of Ten Vibrations.	Mean Temperature.	Mean Time of Ten Vibrations.	Place of Observation, &c.
	Hours.	Min.	Secs.	Fah.°	Inch.		Fah.°	Secs.	Fah.°	Secs.	
	P.M. 4	10	47.6	31							In small Observatory,
5.		22	45.2	29½	4	200	30.2	35.88	30.2	35.880	out of doors, Dec. 7, 1835. Bache.
	P.M. 5	31	36.0	86							
		43	40.0	90	+4*	200	88	36.20			
	5	46	48.8	92							
6.		58	53.2	92	+4	200	92	36.24	90.0	36.220	Bache.
	P.M. 7	49	22.4	31							
	8	01	20.8	32	+4	200	31.5	35.92			
	8	04	42.8	32							
7.		16	42.2	31	+4	200	31.7	35.97	31.6	35.945	Bache.
	P.M. 11	08	10.6	86							In the house, Feb. 1st,
		23	05.6	80	3½	250	84.0	35.80			1836.
	11	26	26.4	80							
8.		38	21.6	72	+4	200	76.0	35.76	80.0	35.780	Bache.
	A.M. 12	13	02.4	52½							Feb. 2d.
		24	54.4	50	+4	200	50.8	35.60			
	12	26	27.4	50							
9.		38	20.4	48	+4	200	49.2	35.65	50.0	35.625	Bache.

* This sign denotes that the gauge was above the mark to which the sign is prefixed.

A comparison of observations 5 and 7, after correcting the latter by an approximate coefficient for temperature, gives the amount of daily variation to be allowed for. Assuming the progress of this variation to be in proportion to the time, a correction is deduced for number 6, which is in the right direction, though small in amount. The coefficient deduced from 5 and 6 is $m = .000,147$. The coefficient before obtained was $m = .000,117$. It would certainly be rash to infer from the small difference thus rendered evident between the values of m, deduced under different circumstances, that the difference resulted from these circumstances. The times of vibration at corresponding temperatures, are greater in the second set of observations than in the first, as well as the differences for a given number of degrees. It is possible that the needle may have undergone a slight change between October and December, a question which future observations may determine. As far as the application to the observations which are to follow is concerned, these coefficients are so near to each other that either might be adopted without sensibly affecting the results. The difference would amount to but .01 second in ten vibrations, for ten degrees of temperature. From 8 and 9 uncorrected for diurnal variation, $m = .000,145$. The times of oscillation being nearly equally before and after midnight, about which time the march of the intensity begins to change its direction, a correction deduced from preceding observations, would probably render the results less accurate than they are without it.

The very close agreement of the two numbers just given for the coefficient, strengthens the opinion, that the difference from the number found in October results from a slight change in the magnetic state of the bar: the circumstances in the second and third sets of observations having been so very different as to local magnetism.

We infer from a comparison of the three values of m, that a coefficient for the correction for temperature, obtained under the circumstances of the second and third sets of observations, may safely be applied to correct, for temperature, the observations made during the summer and autumn.

The following table contains the observations made to obtain the correction to apply to needles C and B. The former has so small a

correction that the observations upon it were quite laboured. It will probably be better not to go into the same detail in stating these results as in the former ones. With this impression we present the following table. The first column contains the number of the observation; the second, the designation of the needle; the third, the mean time at which the set of observations was made; the fourth, the number of oscillations from which the time of ten contained in the sixth has been calculated; the fifth, the mean temperature; the seventh, remarks, &c.

TABLE No. IV.

Observations for the Correction for Temperature of Needles C *and* B.

No. of Observation.	Designation of Needle.	Hours.	No. of Vibrations.	Mean Temperature. Fah.°	Mean Time of Ten Oscillations. Secs.	Remarks, &c.
						Bache, observer.
1	C.	2.1	550	47.8	32.005	February 1, 1836. In doors. Gauge $3\frac{1}{2}$ to $+4$.
2		4.5	1226	87.8	32.044	Jar leaks much, frequently exhausted. Sets of from [150 to 250 observations.
3		7.7	400	65.5	31.980	Gauge $3\frac{1}{2}$ to 4.
4		9.4	450	48.0	31.930	" 4 and above.
						Bache, observer.
5	B.	5.3	400	37.7	48.230	In doors. February 4th. Gauge about 4 inches.
6		7.7	320	89.9	49.085	Gauge $3\frac{1}{2}$ to 4.
7		9.6	284	45.2	48.260	" above 4. Jar leaks badly.

Needle B presents a curious case of correction for temperature. The diurnal variation shown from observations 1 and 3 is greater than the correction for eighteen degrees of temperature. This fact was perceived during the experiments, and led to the very frequent repetitions of the experiment at 87.8°, No. 2 of the table. Using observations 1 and 4 for the correction for change of intensity, and assuming that change to have been regular, observations 1 and 2 give for the coefficient of the correction for temperature,

$$m = .000{,}049,$$

And 1 and 3 give $m = .000{,}056$

$$\text{Mean } m = .000{,}052$$

The progress of intensity within doors, as shown by observations 1 and 4, is contrary to that of the ordinary diurnal variation. This was correct, however, as was shown by six sets of observations between 3 h. 51′ and 5 h. 49′, at temperatures between 83.3 and 91.8°. The time of ten oscillations diminished from 32.115 to 32.035.

The same fact recurs in the observations on the 4th of February. From these, numbered 5, 6 and 7, allowing for the diurnal change of intensity deduced from 5 and 7, the value of m, for needle B, is, $m = .000,357$.

This supposes 7 to be reduced to the temperature of 5, by an approximate coefficient.

The correction obtained in 1834 for this same needle was $m = .000,277$.

It would seem to be rather more susceptible to changes of temperature now than at the former time. The difference however is small, amounting to about .04 of a second in ten vibrations, for ten degrees of the thermometer.

The coefficients used in correcting the observations which follow, are brought together in the following table.

TABLE V.

Correction for Temperature of Needles 1, 2, B, A *and* C.

First Series.	Value of m.	Second Series.	Value of m.
Needle No. 1	.000,436	Needle A	.000,117
" 2	.000,423	" C	.000,052
" 3	.000,277	" 3 (B)	.000,357

As far as we may be allowed to infer from these observations, the correction for temperature depends for its amount upon the degree of *hardness*, or temper, of the material of the needle; in other words, upon the same property which causes a needle to retain or to lose a charge once given to it.

Nos. 1 and 2, of different dimensions, but of the same material, have sensibly the same correction. C, which is certainly the hardest of the set, has a very small correction. The prismatic bar A has a correction intermediate between the two cylinders C and 3 (B), which

are similar in their general proportions. The effects of figure and of relative dimensions seem to be without influence upon the result.

In all cases pains were taken to allow the needles time to arrive at the temperature of the inclosure, but observations made at intervals during the heating or cooling seem to show that this precaution was not essential.

These observations conclusively show the importance, and indeed the necessity, of determining a specific correction to be applied to each needle used in a series of observations for intensity. They confirm in this respect conclusions to which the observations of captain Sabine for obtaining the same correction, would seem to lead. The variation of these coefficients from each other, as well as from those of captain Sabine, and from that quoted as having been determined by professor Hansteen, agrees in the conclusion to which they lead. It is the more necessary to call special attention to this point, because the coefficient of professor Hansteen has been applied in the reduction of the observations (Royal Soc. Trans. 1828) for the relative intensities at Paris, London and Edinburgh, and more recently in a very extensive series of observations by M. Quetelet of Brussels, whose activity in this branch has of late years been particularly prominent.

A further inference may be deduced from these observations, viz. that a sensible change in the magnetic state of a bar, will be attended by a change in the correction to be applied for temperature. So that a correction once obtained should not be used after such a change has taken place in any considerable degree. In an extensive series of observations, it would therefore be necessary to investigate this correction during the time of making the observations, or before the series was commenced and after its completion.

In applying the correction for temperature, it is convenient, and generally admissible, to take for the multiplier of the coefficient just determined, a mean time of vibration, instead of the actual time in a given case.

That is, to take for the value of T,

$$T = T' - T'' . m (t' - t),$$

where T'' represents the mean time referred to. When the correction

is not large, on account either of the value of m, or of $t' - t$, the differences will fall much below the errors in the observed times of oscillation.

CORRECTION FOR ARC.

In many observations in the First Series, the horizontal oscillations were performed through arcs of very different extent. With needle No. 1, the semi-arc of vibration at the commencement of the experiment was, in some cases, 30°, and in others not more than 20°, the arc at the conclusion of the experiment depending, of course, upon its duration. Similar variations occur with the other needles. The most simple method, therefore, of rendering the results comparable is to reduce the times of oscillation to what they would have been in indefinitely small arcs. The formula for this purpose is the same with that investigated by Borda for the pendulum.* By applying the known values of the arcs observed at beginning and ending the experiment, the times are reduced in the tables which follow. Some error is, no doubt, introduced, particularly when these arcs are large, by the difficulty of observing accurately the extent of the arc of vibration, To diminish these, as far as possible, the arcs of vibration should be reduced to the smallest practicable limit, in order that the times in the different arcs may not vary too rapidly. The practice of oscillating in different arcs leading to a troublesome correction, is to be avoided. We find as the greatest semi-arc of observation suitable to be employed in such observations about fifteen degrees. The oscillation in a rarefied medium permits this to be much reduced.

In the Second Series all the observations were made within the same arcs, and are directly comparable. Needle A made 300 oscillations between the semi-arcs of 4° and 2° when the mercury gauge stood at three inches. At the same pressure C and B made 300 oscillations, between 6° and 2°. In such small arcs, the difference in the

* $$T' = T\left(1 - \frac{\text{Sin. }(A + a)\text{ . Sin. }(A - a)}{32\ M\ (\text{Log. Sin. }A - \text{Log. Sin. }a)}\right)$$
in which T′ is the reduced time of a given number of vibrations; T, the observed time; A and a the arcs at beginning and ending; M, the modulus of the common logarithms.

times of vibration resulting from differences of arc are entirely insensible.

We proceed now to give the observations and calculations for the magnetic intensity at the several places named in the title of our memoir.

RELATIVE HORIZONTAL INTENSITIES AT PHILADELPHIA AND WEST POINT.

Before giving the tables of observations at these two places, we propose to state the different occasions on which the observations were made.

First Series.

The first observations were made at West Point on the 21st of April 1834, with needle No. 1. This needle was then taken to Philadelphia, its rate ascertained (May 16th and 20th), and the needle returned to West Point, where it was observed, at intervals, during five weeks (from June 2d to July 8th). In this last period 3558 oscillations were observed. The same needle was oscillated at Philadelphia on the 5th of August, at West Point on the 13th, and again at Philadelphia on the 20th of the same month. These repeated transfers completely guard against the effect of change of rate in the needle.

No. 3 was first oscillated at West Point on the 23d of April, and again between the 28th of May and 9th of June. It was then transferred to Philadelphia, where it was observed on the 26th of June and 12th of July. It was taken to West Point and oscillated on the 7th and 8th of August, and finally observed at Philadelphia on the 20th and 25th of August.

This series comprises 6478 oscillations at West Point, and 7069 at Philadelphia.

The observations at Philadelphia were made at two different places in the city. In part of the series the apparatus was placed in the open air upon a marble column, and in the other part, in a small observatory; both in the yard attached to professor Bache's dwelling.

The observations at West Point were made upon a small brick column, north of professor Courtenay's house.

It is certain, that considerable differences in local attraction exist at different positions of this highland station. The place of observation is at the base of the hills which inclose, on the west, the table land upon which the buildings of the Military Academy are situated.

The series embracing observations at different hours of the day, with different states of weather, &c., are the more valuable, as presenting a nearer approximation to the mean intensity. In all the remarks and calculations which follow, the intensity is assumed to be constant.

The times, at West Point, were observed by a chronometer by Parkins and Frodsham, of excellent character: those at Philadelphia by a pocket chronometer by Barraud, and by one by French, both of good character. The daily rates were too small to produce any sensible difference by correcting the observations for them.

In the following table, No. VI., the first column contains the number of the observation; the second, the designation of the needle; the third, the date of observation; the fourth, the time of beginning; the fifth, the duration of the experiment; the sixth, the number of vibrations; the seventh, the mean temperature; the eighth, the arcs at beginning and ending; the ninth, the duration of experiment corrected for arc; the tenth, the duration corrected for arc and temperature; the eleventh, the time of ten vibrations corrected for arc and temperature; the twelfth, the state of the weather; and the thirteenth, the names of the observers.

The table of observations at West Point, No. VII., is arranged in a very similar manner to that just described.

The temperature to which the results are reduced is 60° Fah.

TABLE No. VI.

Observations at Philadelphia.—First Series.

No. of Experiment.	Designation of Needle.	Date of Experiment.	Time of Beginning Experiment.			Duration of Experiment.	No. of Oscillations.	Mean Temperature.	Arc at Beginning and Ending.	Duration of Experiment corrected for Arc.	Duration of Experiment corrected for Arc and Temp'ture.	Corrected Time of Ten Oscillations.	State of the Weather.	Observers' Names.
			Hours.	Mins.	Sec.	Secs.		Fah.°	Degs.	Secs.	Secs.	Secs.		
1	No. 1.	May 16	P.M. 6	13	13.8	2209.8	480	60.0	35 to 5	2198.1	2198.1	45.79	Clear. Cumulus.	H. D. Rogers and Bache.
2	"	" 20	" 5	29	42.2	2049.8	440	85.7	"	2038.9	2015.7	45.81	Hazy.	Bache.
3	"	Aug. 5	A.M. 7	21	09.6	3035.6	654	83.5	20 to 3	3029.9	2998.4	45.84	Clear.	"
4	"	" "	" 8	33	04.8	1035.6	232	87.5	20 " 10	1081.3	1068.1	46.04	"	"
5	"	" "	P.M. 7	04	56.0	2372.0	510	87.2	20 " 3	2367.5	2339.2	45.87	"	"
6	"	" 20	" 3	58	10.8	2082.4	452	92.9	19 " 3	2078.8	2048.7	45.33	Clear. Cumulus.	" "
7	"	" "	" 8	14	12.0	2486.8	538	93.5	20 " 3½	2481.7	2444.9	45.45	"	"
8	"	" "	" 10	24	33.6	2212.4	486	55.5	20 " 3	2208.2	2212.6	45.53	"	"
9	"	" 25	" 8	10	05.2	1660.4	356	99.1	20 " 5	1656.1	1627.4	45.71	Cloudy.	"
10	"	" "	" 11	51	16.4	1684.4	362	98.0	20 " 5	1680.0	1651.7	45.63	"	"
14	No. 3.	June 26	P.M. 7	10	00 0	1086.8	220	82.5	30 " 5	1082.1	1071.3	48.68		Bache.
15	"	July 12	" 4	31	28.0	1411.8	290	84.5	15 " 2	1410.4	1395.1	48.11	Cloudy.	"
16	"	" "	" 5	14	00 0	1460.8	300	83.5	15 " 3	1459.0	1443.8	48.13		"
17	"	Aug. 20	" 6	04	39.6	1290.8	264	84.4	20 " 3	1288.4	1274.5	48.28	Clear.	"
18	"	" 25	" 9	51	22.2	894.0	182	102.2	20 " 5	891.7	875.0	48.08	Cloudy.	Bache and Courtenay.

Needle No. 1. Whole No. of Vibrations 4510; Whole time, 20,604.8 Secs.; Mean Time of Ten Vibrations, 45.687 Secs.
3. " 1256; " 6,059.7 " " 48.246 "

TABLE No. VII.

Observations at West Point.—First Series.

No. of Experiment.	Designation of Needle.	Date of Observation.	Duration of Experiment.	No. of Oscillations.	Temperature of Needle.	Arc at Beginning and Ending.	Duration of Experiment corrected for Arc.	Duration of Experiment corrected for Arc and Temp'ture.	Corrected Time of Ten Vibrations.	Observers' Names.
			Secs.		Fah.°	Degs.	Secs.	Secs.	Secs.	
1	No. 1.	April 21	953.8	200	63	25 a 15	945.6	944.3	47.22	Courtenay and Bache.
2	"	" 22	752.5	160	49	25 a 10½	758.4	752.1	47.01	"
3	"	June 2	960.5	200	74	30 a 15	952.2	946.5	47.32	Courtenay and Cram.
4	"	" "	1142.4	238	"	"	1132.6	1125.8	47.30	"
5	"	" 9	971.7	200	89.2	"	963.3	950.8	47.54	"
6	"	" "	1018.7	210	"	"	1010.0	996.9	47.47	"
7	"	" 14	1958.5	410	66½	30 a 5	1950.0	1944.6	47.43	"
8	"	July 1	1913.7	400	74	30 a 4	1906.3	1894.9	47.37	Courtenay.
9	"	" "	1916.5	"	79	30 a 5	1908.2	1892.1	47.30	"
10	"	" 3	1919.2	"	74½	"	1910.9	1899.0	47.47	"
11	"	" 7	1926.8	"	82	30 a 6½	1917.2	1898.5	47.46	"
12	"	" 8	1924.0	"	81	"	1914.4	1896.4	47.41	"
13	"	" 12	955.5	200	71	20 a 10½	951.5	946.9	47.34	"
14	"	" "	955.7	"	78	20 a 7	952.8	945.3	47.26	"
15	"	" "	956.0	"	72½	20 a 7½	953.1	947.9	47.39	"
16	"	Aug. 12	1675.5	348	86	20 a 3	1672.3	1653.0	47.50	Courtenay and Bache.
25	No. 3.	April 22	515.5	100	52	30 a 14	501.4	502.5	50.25	"
26	"	May 28	515.2	"	64	40 a 19	508.0	507.4	50.74	Courtenay and Cram.
27	"	" 30	516.1	"	"	40 a 22	508.1	507.5	50.75	"
28	"	June 2	517.0	"	71½	40 a 17	510.4	508.8	50.88	"
29	"	" 9	520.7	"	89¼	39 a 21	513.1	508.9	50.89	"
30	"	Aug. 7	1537.8	300	82	30 a 4	1531.9	1522.5	50.75	Courtenay.
31	"	" 8	1543.9	"	84	"	1537.9	1527.5	50.92	"

Needle No. 1. Whole No. of Vibs. 4566; whole time, 21,635.0 secs.; Mean time of 10 Vibs. at 60° 47.381.
3. " 1100; " 5,585.1 " 50.774.

The horizontal intensities deduced from a comparison of these last results with those obtained at Philadelphia, are, from No. 1, .92977; and from No. 3, .90290, the horizontal intensity at Philadelphia being assumed as unity. The relative weights of the observations with the two needles, taking the whole number made with each needle as belonging to one set of observations, will be, according to the formula of Gauss,*

$$\text{For No. 1,}\ 2\times\frac{4566\times4510}{9076}=4540;$$

$$\text{And for No. 3,}\ 2\times\frac{1100\times1256}{2356}=1174.$$

The mean horizontal intensity thus deduced is, .92424. An arithmetical mean of the two intensities would have given .91633, a number differing sufficiently from that just found, to make the calculation worth pursuing, notwithstanding that it is less than the difference of the intensities determined by the two different needles.

SECOND SERIES.

These observations were made on the 7th and 8th of September 1835, at West Point, and in September and October in Philadelphia. They were made in the vacuum apparatus, and although the number of observations is not equal to that of the first series, the mean error is so much diminished by the superior accuracy of the results in the rarefied medium, that the weight of the observations is very much greater than that of the more numerous ones of the first series.

The following tables, Nos. VIII. and IX., are arranged nearly as the preceding ones, and require no specific description.

The table for Philadelphia contains observations with needle No. 3 (B), for comparison with others with the same needle at different places. This needle was not oscillated at West Point.

* Baily in Trans. Astr. Soc. Lond., Vol. II. p. 19.

TABLE No. VIII.

Observations at Philadelphia.—SECOND SERIES.

No. of Experiment.	Designation of Needle.	Date of Observation.	Time of Beginning.	Duration of Experiment.		Mean Temperature.	No. of Oscillations.	Time of Ten Oscillations.	Time of Ten Oscillations corrected for Temperature.	Weather and Remarks.	Observer, &c.
			Hours.	Mins.	Sec.	Fah.°		Secs.	Secs.		
		1835.									
1	A	Sept. 19	P. M. 5.4	18	00.2	68.2	300	36.01	36.02	Cloudy. E. Nimbus.	Bache.
2	"	" 30	" 3.5	18	00.6	63.9	300	36.02	36.05	Cloudy. Wind N. W.	Place of
3	"	" "	" 3.8	15	00.4	63.1	250	36.02	36.05	Cumulus.	Observation,
4	"	Oct. 5	" 4.2	18	01.4	72.0	300	36.05	36.04	Cloudy. N. E. wind.	Small
5	"	" "	" 4.6	18	01.2	71.2	300	36.04	36.04	Cumulo-stratus.	Magnetic
6	"	" "	" 6.5	14	58.0	33.7	250	35.92	36.07	In ice.	Observatory
7	"	" "	" 7.0	17	56.4	33.7	300	35.88	36.03	"	in rear of
8	"	" "	" 8.7	18	00.4	61.7	300	36.01	36.05	"	Prof. Bache's
9	"	" "	" 9.0	18	01.0	62.9	300	36.03	36.06	"	dwelling,
10	"	" "	" 10.5	15	03.6	91.2	250	36.14	36.05	Heated by lamps.	Chesnut St.
11	"	" "	" 11.2	18	05.0	88.5	300	36.17	36.09	"	near Schu'kll
12	"	" 17	" 3.9	12	02.4	77.2	200	36.12	36.09	Cloudy. S. E.	Sixth.
13	C	Sept. 18	P. M. 5.3	16	05.2	69.4	300	32.17	32.17	Clear. S. E. Cirro-	Bache.
14	"	" "	" 5.6	16	05.6	68.1	300	32.19	32.19	Cumulus—rare.	Place
15	"	" 19	" 3.9	16	06.4	69.5	300	32.21	32.21	Cloudy. Nimbus.	of
16	"	" "	" 4.4	16	05.4	69.0	300	32.18	32.18	Wind E.	Observation
17	"	" "	" 5.0	13	24.4	68.0	250	32.18	32.18	"	as above.
18	B	Oct. 5	P. M. 3.3	20	26.0	74.0	250	49.04	48.97	Cloudy. N. E.	Bache.
19	"	" "	" 3.6	20	27.2	73.4	250	49.09	49.03	"	Same Place of
											Observation.

Mean Time of Ten Oscillations at 70° Fah. by A, 36.053 in Semi-arcs of 4 a 2°. Total No. of Vibs. 3350.
" C, 32.186 " 6 a 2°. " 1450.
" B (3) 49.000 " " " " 500.

TABLE No. IX.

Observations at West Point.—SECOND SERIES.

No. of Experiment.	Designation of Needle.	Date of Observation.	Time of Beginning.	Duration of Experiment.		Mean Temperature.	No. of Oscillations.	Time of Ten Oscillations.	Time of Ten Oscillations corrected for Temperature.	Weather, &c.	Observer, &c.
			Hours.	Mins.	Secs.	Fah.°		Secs.	Secs.		
1	A	Sept. 7	P. M. 5.0	18	48.4	69.9	300	37.61	37.61	Clear. Wind N.	Bache and
2	"	" "	" 5.3	18	47.6	66.8	"	37.59	37.60	of W.	Courtenay.
3	"	" 8	A. M. 10.1	18	44.7	64.0	"	37.49	37.52	Clear. W.	Same locality as
											in former Ob-
4	C	Sept. 8	A. M. 10.9	16	44.6	70.3	302	33.27	33.27	Clear. W.	servations.
5	"	" "	" 11.2	16	37.6	69.5	300	33.25	33.25		
6	"	" "	" 11.6	16	44.6	71.9	302	33.27	33.27		

Mean Time of Ten Oscillations at 70° Fah. by A, 37.577 in Semi-arcs fr. 4 to 2°. No. of Oscillations 900.
" " " C, 33.263 " 6 to 2°. " 904.

The horizontal intensity compared with that at Philadelphia is, from A, .92053, and from C, .93630. The relative weights to be attached to the results with the two needles are, respectively, 1419 and 1113.

We now proceed to compare the horizontal intensities, deduced from both series of observations, to obtain the mean.

As the methods of observation in the two series are liable to different errors, and the number of observations are different, we have allowed to the results obtained by them, weight in proportion to the number of observations directly, and the square of the mean error inversely. The mean error is hardly attained, even in the case of the greatest number of sets of observations of the second series; but an approximation to it will afford a far more satisfactory mode of deducing the mean intensity than could be obtained by an indiscriminate mean of the results.

The numbers found for the weight of the observations with each needle in the two series, have been of course used instead of the number of observations, as referred to in the preceding paragraph. And a mean error has in like manner been deduced from the combined observations with each needle at the two places. Using these numbers, we have obtained the following for the relative weights of the observations with each needle.

First Series.	No. 1,	2728	Second Series.	A,	29319
"	3,	476	"	C,	1136.

By the use of these numbers, and of the horizontal intensities already obtained, we have for the mean, $h' = .92156$.

The superiority of the method in the rarefied medium, cannot better be shown than by stating, that the mean error with needle A, supposing it reached in the observations, was .022 seconds in about $36\frac{1}{2}$ seconds, while, with No. 1 in the first series, it was .129 seconds in about 46 seconds, or six times the former.

The probable error* in the time of ten vibrations of Needle A is, .0005 second.

* Deduced from the formula $P = 85\frac{e}{\sqrt{n}}$. Young, Phil. Trans. 1819, p. 77.

RELATIVE INTENSITIES AT NEW YORK AND PHILADELPHIA.

The observations to be presented belong to both series. Those of the first are retained as second in number to the Philadelphia and West Point observations of the same series. The observations of the first series were made in April and in August 1834. In the first set I had the kind assistance of professor Renwick; the times were observed with a pocket chronometer belonging to him, the rate of which was ascertained, but was not such as to affect the results sensibly. At his suggestion the observations made at Columbia College green were checked by a set made near Bellevue. Another set was made in the north part of the city, but there appeared no difference of local attraction in the three places. The pocket chronometer used in the August observations was of good character.

TABLE No. X.

Observations at New York.—FIRST SERIES.

Designation of Needle.	Date of Observation.	Time of Beginning. Hours.	Temperature of Needle. Fah.°	Number of Oscillations.	Arc at Beginning and End. Degs.	Observed Time of Ten Vibrations. Secs.	Time of Ten Vibrations corrected for Arc and Temperature. Secs.	Weather, &c.	Observers and Places of Observation.
	1834.								
No. 1.	April 25	A. M. 8.0	42	330	25 a 5	46.03	46.24	Wind N. W.	Prof. Bache & Renwick.
"	" "	" 8.5	"	320	"	46.05	46.26	Nimb. & Snow.	Col. College Green.
"	" "	P.M. 12.6	44.5	350	"	46.20	46.36	Slight Rain.	Bache. Rose hill.
"	" 24	" 6.1	50	280	"	46.24	46.28	W'd high N.W.	Bache. No. 31, 5th St.
"	August 7	A. M. 6.2	76	548	20 a 3	46.98	46.56	Clear. N. W.	Bache. Colum. College Green.
Needle No. 1; No. of Vibrations 1828; Time of 10 Vibrations at 60°, reduced for Arc, 46.340 Secs.									

Comparing this result with the mean time of No. 1 at Philadelphia, we have the relative horizontal intensity at New York, .97202. The time of ten oscillations as observed in August, indicates a real diminution of intensity in the magnetism of the needle or of the earth. The observations at Philadelphia do not indicate a change in the magnetism of the needle, we have therefore retained this result, and used it in obtaining the mean.

SECOND SERIES.

The observations of the second series were made in August and September 1835, with needles A and C. The following table contains the results.

TABLE No. XI.

Observations at New York.—SECOND SERIES.

No. of Experiment.	Designation of Needle.	Date of Observation.	Time of Beginning. Hours.	Duration of Observation. Min.	Sec.	Temperature of Needle. Fah.°	No. of Oscillations.	Time of Ten Vibrations. Secs.	Time of Ten Vibrations corrected for Temperature. Secs.	Weather, &c.	Observer, &c.
1	A	August 5	P. M. 5.1	18	35.6	71.0	302	36.94	36.94	Cldy. S.W.	Bache. Place of Observ.
2	"	" "	" 5.6	19	12.8	71.0	310	36.95	36.95	Cumulus.	Yard in rear of dwell-
3	"	" 6	A. M. 10.8	20	19.0	68.9	330	36.94	36.94	Cloudy. E.	ing of E. Martin, Esq.
4	"	" "	" 11.3	17	07.0	69.7	278	36.94	36.94	Nimbus.	No. 31, 5th Street.
5	"	Sept. 10	P. M. 5.1	17	33.0	76.2	284	37.07	37.04	Cldy. S.W.	Bache.
6	"	" "	" 5.4	15	56.9	75.2	258	37.09	37.06	Cumulus.	
7	"	" "	" 5.7	18	39.2	73.5	202	37.06	37.04	"	
8	C	Sept. 10	P. M. 7.5	16	19.4	73.5	296	33.08	33.08	Cldy. S.W.	Bache.
9	"	" "	" 7.8	16	32.2	71.0	300	33.07	33.07	Cumulus.	

Mean Time of Ten Oscils. at 70° Fah. in Aug. by A, 36.941 in Semi-arcs of 4° a 2°. No. of Vibs. 1220.
" " " Sept. " " 37.047 " " " " 744.
" " " " " C, 33.075 " 6° a 2°. " 596.

The times of vibration observed in the beginning of the month of August are all less than those observed in September, probably from a slight change in the magnetism of needle A, with which the observations were made. This change, however small, renders it expedient to compare only the September observations with those at Philadelphia. From the mean of these, we have,

Relative horizontal intensity at New York, by A, 0.94707,
" " " " C, 0.94697.

These results agree very well together, but not very well with that from the first series, Table X. As from the comparisons at West Point and Philadelphia, there does not appear to have been a real change in the intensity of the earth's magnetism between the times at which the two series of observations were made, it will probably be more accurate to take the mean of the two determinations. Allowing weight

to the different sets according to the method before explained, we have for the mean horizontal intensity,

$$h'' = .94705.$$

By comparing this result with the mean of the observations made in full air, it will be seen, that in determining the value of h'' the first series of observations has hardly any weight, and we propose in the cases which follow, where observations were made by both methods, to omit those of the first series entirely. In no one of the cases alluded to were the observations of the first series as numerous as at New York. And the comparison has probably been carried sufficiently far to show the superior value of the results in rarefied air; the comparisons having been made according to principles involving the mean error to which the methods are liable, as deduced from the observations themselves.

MAGNETIC INTENSITY AT NEWPORT, R. I.

The observations at Newport were made during a visit there in the months of August and September 1835. They all belong to the Second Series, and were made in nearly the same place, and, with few exceptions, about the same period of the day. The results with all three of the needles agree very nearly; the greatest number of observations having been made with needle A, and the least with No. 3 (B).

We have abridged this table by omitting the column for the duration of the observations.

TABLE No. XII.

Observations at Newport, R. I.—SECOND SERIES.

No. of Experiment.	Designation of Needle.	Date of Observation.	Hour of Beginning.	Temperature. Fah.°	No. of Vibrations.	Observed Time of Ten Vibrations. Secs.	Corrected Time of Ten Vibrations. Secs.	Weather, Wind, &c.	Observers, &c. Place of Observation.
		1835.							
1	A	Aug. 19	A.M. 10.1	86.2	350	38.14	38.07	Clear. S. W. Cirrus.	Bache and Courtenay.
2	"	" "	" 10.5	87.2	348	38.09	38.01		
3	"	" 20	" 10.4	76.5	350	38.00	37.97	Clear. Cloudless. S. E.	
4	"	" "	" 10.8	77.5	352	37.99	37.95	At 8 A. M. North.	In the Garden in rear of
5	"	" 21	" 10.7	74.7	350	38.03	38.01	Cloudless. W. S. W.	Wm. Littlefield, Esq.
6	"	" "	" 11.3	76.0	300	38.00	37.97		corner of High and
7	"	" 25	" 10.1	75.2	300	38.06	38.03	Clear. S. W.	Mary streets.
8	"	" 31	" 10.7	75.2	300	38.06	38.03	Overcast. S W.	
9	"	" "	" 11.1	75.6	306	38.03	38.00		
10	C	Aug. 25	A.M. 11.1	78.2	300	33.88	33.87	Clear. S. W.	Bache and Courtenay.
11	"	" 26	" 10.1	78.7	300	33.97	33.96	S. W. Clear.	
12	"	" "	" 10.4	80.0	284	33.98	33.96		
13	"	" 27	" 9.7	73.6	300	33.93	33.93	Clear. N. W.	
14	"	" "	" 10.0	74.5	236	33.95	33.94		
15	"	" 31	" 12.4	78.7	300	33.93	33.92	Overcast. S. W.	
16	"	" "	" 12.7	78.5	300	33.92	33.91		
17	No 3	Aug. 25	A.M. 10.9	77.5	164	51.57	51.44	Light haze. S. W.	Bache and Courtenay.
18	"	" "	" 11.2	77.9	250	51.57	51.43		
19	"	" 27	P.M. 5.6	71.5	250	51.51	51.48	Clear. N. W.	
20	"	" 31	A.M. 12.0	78.5	150	51.67	51.51	Overcast. S. W.	

Mean Time of Ten Vibs. at 70° Fah. by A, 38.004 in Semi-arcs of 4° to 2°. Total No. of Vibs. 2956.
" " " C, 33.927 " 6° to 2°. " " 2020.
" " " (B) 3, 51.465 " " " " 814.

From these observations are deduced the following relative horizontal intensities, the same element as Philadelphia being taken as unity.

From Needle A, 0.89996
" " C, 0.90000
" " 3, 0.90651

The mean of these, taken according to principles heretofore stated, gives for the relative horizontal intensity, $h''' = 0.90086$.

INTENSITIES AT PROVIDENCE, R. I., SPRINGFIELD, MASS., AND ALBANY, N. Y.

For the horizontal intensities at these several places, we rely entirely upon the SECOND SERIES of observations.

The observations at Providence were made on a visit there for the purpose; and the kind assistance of professor Caswell, of Brown Uni-

versity, rendered them easy, notwithstanding the unfavourable condition of the weather. The place of observation was north of the College buildings. It will be seen that the results here obtained accord very well with the deductions from numerous observations at Newport, which is about thirty miles south of Providence.

In crossing from Providence to Albany, N. Y., one of us observed at Springfield, Mass., seventy-five miles west from the former place. The place of observation was highly favourable, being in an open field, remote from buildings, and well shaded from the sun.

At Albany the place of observation was less favourable, being inclosed by buildings.

The results are given in the following table.

TABLE No. XIII.

Observations at Providence, Springfield and Albany.

No. of Experiment.	Designation of Needle.	Date of Observations, and Place.	Time of Beginning.	Temperature.	No. of Oscillations.	Time of Ten Oscillatoins.	Corrected Time of Ten Oscillations.	Weather, Wind, &c.	Locality of Observations and Observers.
			Hours.	Fah.°		Secs.	Secs.		
		Providence, R. I., 1835.							
1	A	Aug. 28	P. M. 1.5	71.0	298	38.08	38.08	Nimbus. S. E. wind.	Bache. Place of Ob-
2	"	" "	" 1.8	70.5	300	38.08	38.08	Showers during Ob-	servation to North
3	C	" "	" 12.6	73.0	300	33.99	33.99	servations.	of N. College Hall,
4	"	" "	" 12.9	71.5	308	33.95	33.95	Rains.	Brown University.
5	No.3	" "	A.M. 11.4	76	264	51.61	51.50		
6	"	" "	" 11.8	75 7	252	51.63	51.52	Rains.	
		Springfield, Mass. 1835.							
7	A	Sept. 4	P. M. 1.7	77.0	298	38.35	38.32	Slightly hazy. Wind	Bache. Place of Ob-
8	"	" "	" 2.0	77.5	302	38.30	38 26	S. by W.	servation on N. E.
9	"	" "	" 2.4	77.8	250	38.30	38.26		side of a large Elm
10	C	" "	" 3.9	78 9	300	34.20	34.18		tree in rear of Pin-
11	"	" "	" 4.3	78.9	300	34.20	34.18		chyn house.
12	No.3	" "	" 4.8	79.4	270	52.12	51.95		
13	"	" "	" 5.2	76.0	250	52.16	52.05		
		Albany, N. Y. 1835.							
14	A	Sept. 6	A. M. 9.7	85.1	256	39.13	39.06	Cloudy. Wind S.	Bache. Place of Ob-
15	"	" "	" 10.2	87.8	300	39.12	39.04	Clouds from S. W.	servation, yard in
16	"	" "	" 10.6	91.5	300	39.16	39.06	Aurora last night.	the rear of Franklin
17	C	" "	" 11.5	88.8	300	34.87	34.82		House, State street.
18	"	" "	" 12.1	90.5	300	34.89	34.84		

Providence.	Mean Time of 10 Oscils., &c. by	A, 38.080	in Arcs of 4° to 2°.	Total No. of Vibs.	598.
	" "	C, 33.970	" 6° to 2°.	" "	608.
	" "	No. 3, 51.510	" "	" "	516.
Springfield.	" "	A, 38.280	" 4° to 2°.	" "	850.
	" "	C, 34.180	" 6° to 2°.	" "	600.
	" "	No. 3, 52.000	" "	" "	520.
Albany.	" "	A, 39.053	" 4° to 2°.	" "	856.
	" "	C, 34.830	" 6° to 2°.	" "	600.

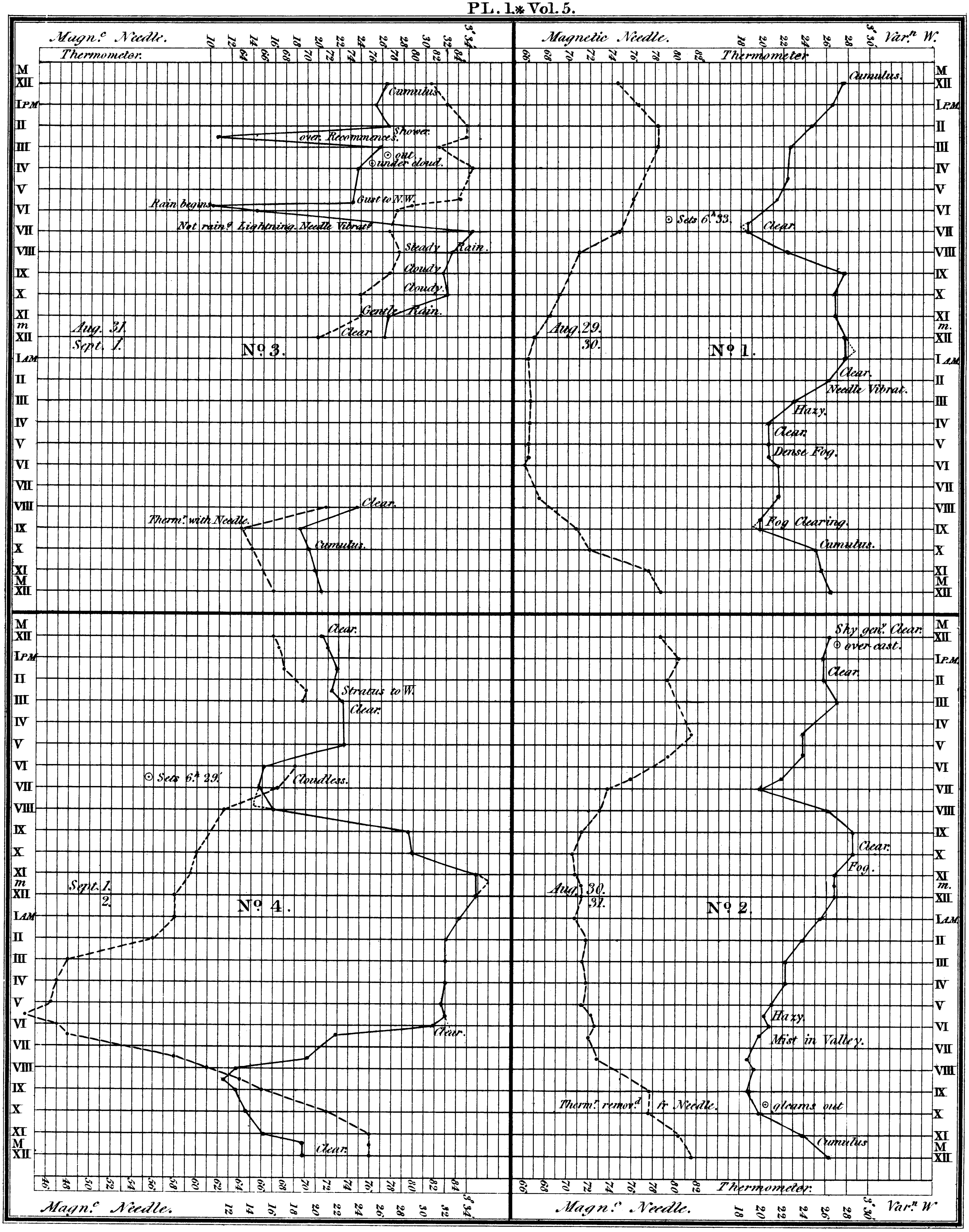
From these are deduced the horizontal intensities given below: the relative weights of the observations, considering them to be liable to the same mean error, and the mean horizontal intensities deduced from a comparison of the different results according to their weights, are as follows.

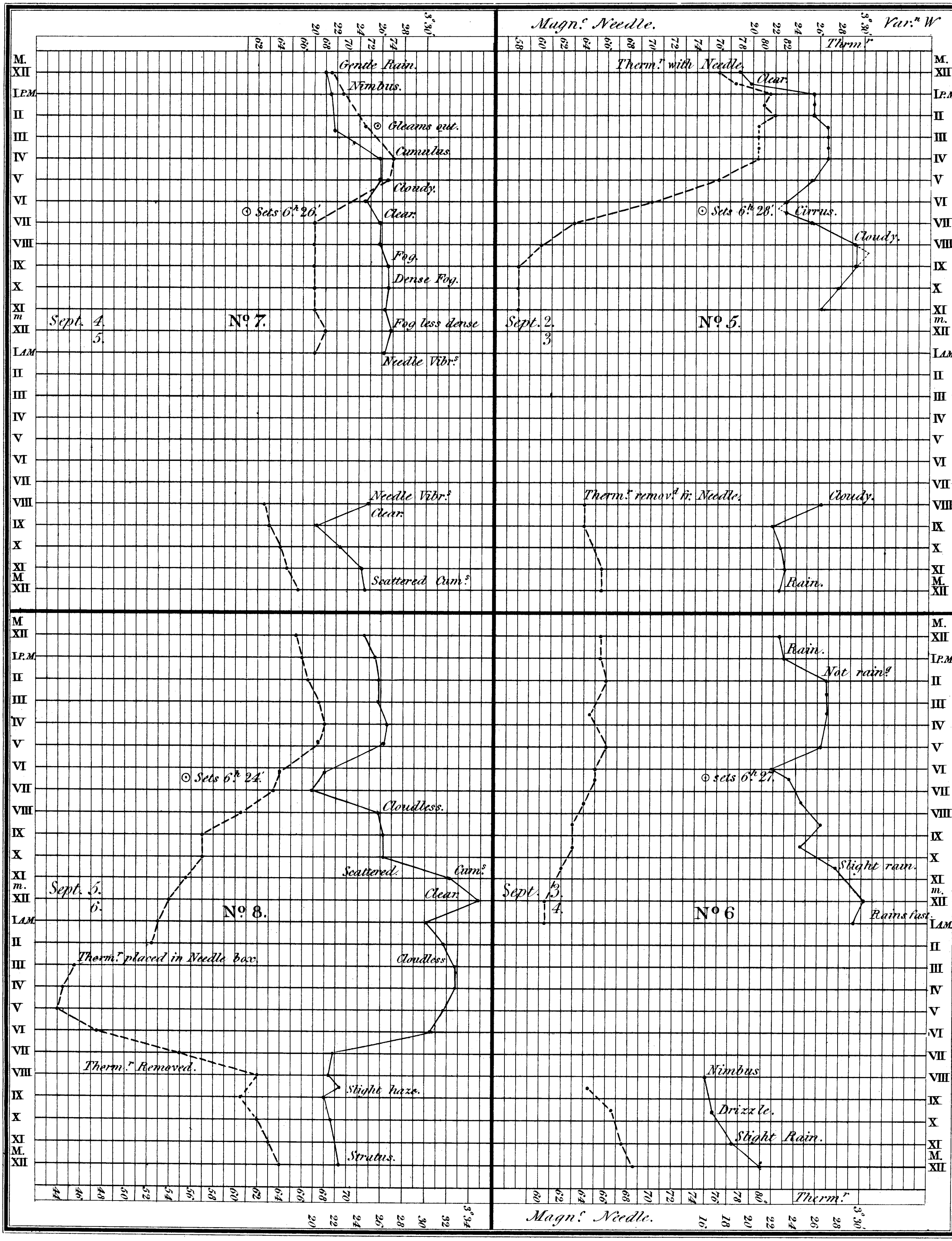
Places.	Relative Horizontal Intensities by Needle.			Weights of Observation by Needle.			Mean Horizontal Intensities.
	A	C	No. 3	A	C	No. 3	
Providence, R. I.	.89637	.89773	.90492	508	428	254	.89869
Springfield, Mass.	.88703	.88673	.88794	678	424	255	.88711
Albany, N. Y.	.85226	.85394		682	424		.85290

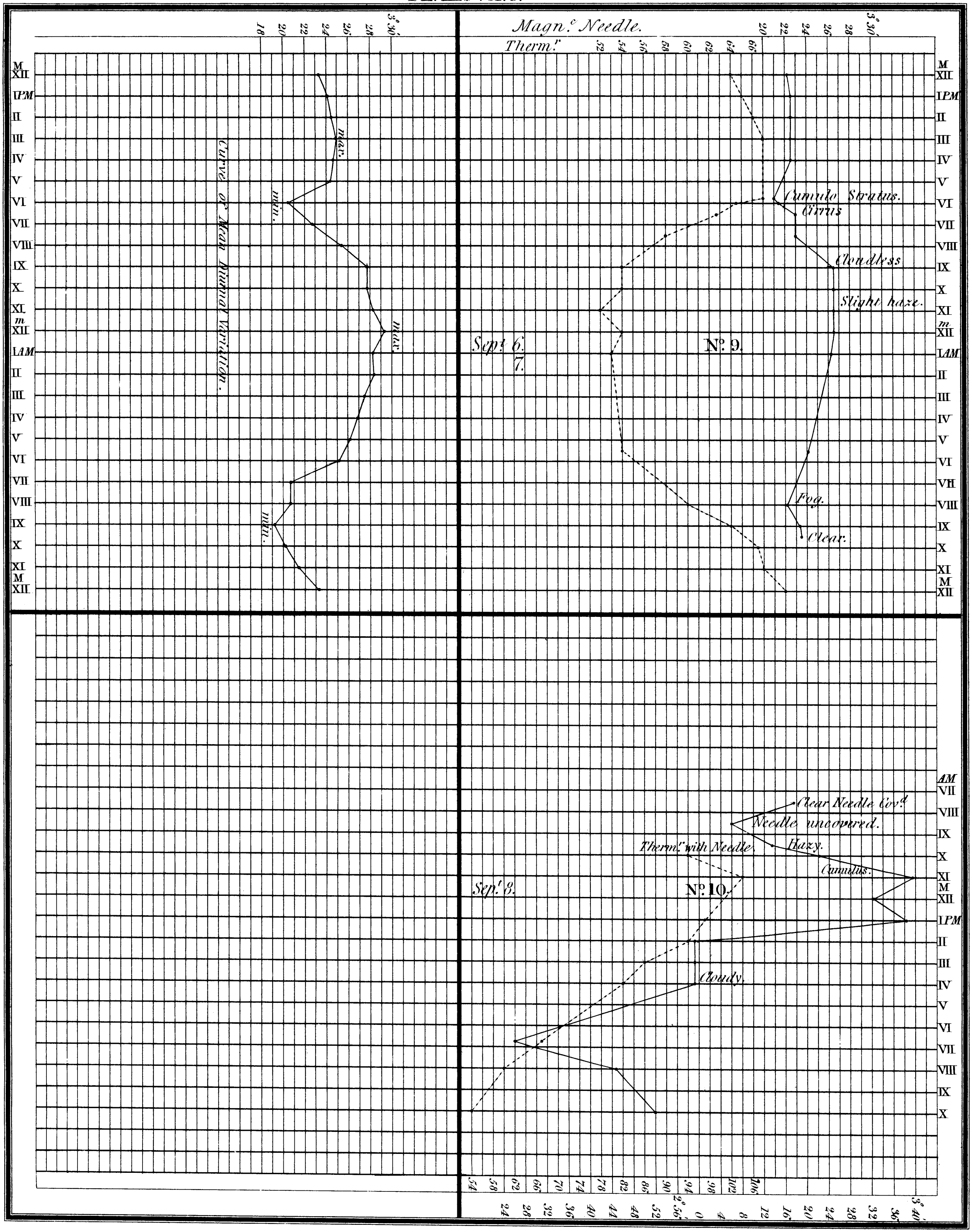
ON THE TOTAL MAGNETIC INTENSITY.

We have already remarked, that we do not consider the dip to be sufficiently well known at any of the places at which we have deduced the horizontal intensities, to admit of combining the results for the total intensity. For example, at Albany the difference of eleven minutes between our observations and those of professor Henry, corresponds to a difference in intensity of 0.01177. The places at which the observations were made lie so nearly upon the line of equal intensity as to render so rude an approximation entirely inadmissible. The general direction thus pointed out for this line, accords with the general direction formerly assigned by captain Sabine.*

* American Jour. Science, Vol. XXII. Letter to Professor Renwick.


Magn.e Needle.
Thermometer.
Magnetic Needle.
Var.n W.
Cumulus.
Shower.
over. Recommences.
⊙ out.
⊙ under cloud.
Gust to N.W.
Rain begins.
Not rain.g Lightning. Needle Vibrat.d
Steady Rain.
Cloudy.
Gentle Rain.
Clear.
Aug. 31.
Sept. 1.
No. 3.
Therm.r with Needle.
⊙ Sets 6h 33.
Needle Vibrat.
Hazy.
Dense Fog.
Fog Clearing.
Aug. 29.
30.
No. 1.
Stratus to W.
⊙ Sets 6h 29.
Cloudless.
Sept. 1.
2.
No. 4.
Sky gen.l Clear.
⊙ over cast.
Fog.
Aug. 30.
31.
No. 2.
Mist in Valley.
Therm.r remov.d fr. Needle.
⊙ gleams out.
M
XII
I P.M.
II
III
IV
V
VI
VII
VIII
IX
X
XI
m.
I A.M.


Magn.s Needle.
Var.n W
Therm.r
No. 7.
Sept. 4. 5.
Gentle Rain.
Nimbus.
☉ Gleams out.
Cumulus.
Cloudy.
☉ Sets 6.h 26'.
Clear.
Fog.
Dense Fog.
Fog less dense
Needle Vibr.s
Needle Vibr.s
Clear.
Scattered Cum.s
No. 5.
Sept. 2. 3
Therm.r with Needle.
Clear.
☉ Sets 6.h 28'.
Cirrus.
Cloudy.
Therm.r remov.d fr. Needle.
Cloudy.
Rain.
No. 8.
Sept. 5. 6.
☉ Sets 6.h 24'.
Cloudless.
Scattered.
Cum.s
Clear.
Cloudless
Therm.r placed in Needle box.
Therm.r Removed.
Slight haze.
Stratus.
No. 6
Sept. 3. 4.
Rain.
Not rain.g
☉ sets 6.h 27'.
Slight rain.
Rains fast.
Nimbus
Drizzle.
Slight Rain.
Magn.s Needle.
Therm.r


Magn.c Needle.
Therm.r
Curve of Mean Diurnal Variation.
max.
min.
Cumulo Stratus.
Cirrus
Cloudless
Slight haze.
Fog.
Clear.
Sept. 6.
7.
No. 9.
Clear Needle Cov.d
Needle uncovered.
Hazy.
Therm.r with Needle
Cumulus.
Cloudy.
Sept. 8.
No. 10.